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Bioactive content and antioxidant capacity of Cape gooseberry fruit

Research Article

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Abstract: At present, Cape gooseberry (*Physalis peruviana*) fruit is one of the less used raw materials of plant origin, which can be used for human nutrition. This fruit, as well as alimentary products made of it, were used by healers in folk medicine in the distant past. The aim of this study was to monitor and evaluate the antioxidant capacity of fresh fruit of three Cape gooseberry cultivars ´Giant´, ´Golden berry´ and ´Inka´. Antioxidant capacity was also tested, on the basis of the scavenging effect of reactive oxygen species (ROS) and lipid peroxidation of methanolic extracts made of fresh fruit. These results were further extended and supplemented with determinates of the vitamin C and total phenolic contents. These analyses were made for three consecutive years. The highest values of antioxidant capacity were observed in the ´Inka´ cultivar (9.31 grams of ascorbic acid equivalents kg^{-1} of fresh mass). In this cultivar, the obtained results were corroborated also in ROS and the contents of vitamin C and total phenolics. Due to a high antioxidant capacity of this fruit species, the results presented should increase its popularity above all as a promising raw material, which can be used for human nutrition.

Keywords: *Physalis peruviana* • *Phenolics, flavonoids* • *Ascorbic acid* • *Reactive oxygen species* • *Lipid peroxidation*

1. Introduction

Depending on the locality, Cape gooseberry (*Physalis peruviana* L.) is grown as an annual or perennial crop. It belongs to the family *Solanaceae* and is indigenous to Peru and Guatemala. In its homeland, positive effects of Cape gooseberry when treating a number of diseases have been known for centuries [1]. Fresh fruit is used as a means to support the immune system of humans [2]. Today, Cape gooseberry has been widely introduced into cultivation in many subtropical areas, but it can also be grown in temperate regions in glasshouses or similar facilities [3].

Cape gooseberry is commercially cultivated in South Africa where two different forms of this fruit species have been selected, *edulis* bearing yellow berries and *violacea* with fruit of deep purple colour [4]. The plant has small round berries with the diameter ranging from 1 to 3 cm, globular to oval in shape and protected with a huge calyx. The pulp is juicy, sweet-and-sour and the berries are usually consumed either fresh in salads or processed as jams, juices, liqueurs, *etc*. [5].

In the human body, reactive oxygen species (ROS) are produced due to physical and environmental stressors and their occurrence is a part of the response of the human immune system to the action of these negative factors. It is well known that antioxidants help to maintain the balance of ROS, through inhibitition and facilitation of the elimination of free radicals [6]. When the ROS free radical balance is disturbed there

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is danger of attack against various biological structures and activation of undesirable metabolic transformations. The final results of the action of these factors are the damage of blood vessels and body tissues as well as precocious senescence [7].

Horticultural crops including fruits, vegetables and grapes represent an important source of antioxidants [8]. Of the antioxidants, compounds with a polyphenolic structure appear in the foreground. For example, flavonoids are well known antioxidants contained in fruits and the antioxidant effects of vitamin C are also significant [9]. The aim of this study was to investigate antioxidant effects of methanolic extracts of Cape gooseberry in a three year study. Experiments were performed with three cultivars, ´Giant´, ´Golden berry´ and ´Inka´ and the following parameters were measured: total phenolic content (TPC), the content of ascorbic acid (AAC) and the contents of flavonoids (TFC). Measured contents were thereafter correlated with the total antioxidant capacity (TAC) of the fruit and also with the inhibitive effects on ROS and lipid peroxidation activity. A similar study has been published [10]; however, in the previous research, whole plants were tested and only one cultivars was examined. In this respect, the work presented in our study is innovative.

2. Experimental Procedures

2.1 Sample collection and preparation for chemical analyses

Fruits were harvested in the experimental orchards of Tomas Bata University, Zlin, Czech Republic within the period of 2009-2011. These orchards are situated in the south-western part of the White Carpathian mountains. The average altitude is 340 m a.s.l., and the mean annual temperature and precipitation are 7.9°C and 760 mm, respectively. The soil type has been classified as Mesotrophic Cambisol [11].

In the locality described above, one-year-old plants were grown in an unheated glasshouse. In all three years if the study, the seeds were sown with spacing 50x40 cm (always on 25th March). Fertilisation with Cererit (Lovochemie, Lovosice, Czech Republic) was performed in the autumn and spring in accordance with the instructions of the Czech Central Institute for Supervision and Testing in Agriculture [11]. Twenty seeds were sown in one place and following germination (a month after sowing) one plant was selected as the test individual and the remaining plants were removed. The period of full bloom always ranged from approximately 60 to 65 days prior to the harvest. The harvest took place at the stage of full ripeness (*i.e.*, on 2nd October 2009, 5th October 2010 and 4th October 2011). In each experimental year, five plants of each cultivar (´Giant´, ´Golden berry´, ´Inka´) were sampled and from each plant ten fruits were randomly sampled so that a total number of 50 fruits were analyzed each year. For chemical analyses, within 24 hours of harvest, fruits were pooled, homogenized in a laboratory grinder (SJ500, MEZOS, Hradec Kralove, Czech Republic), and sampled. The average sample was obtained by dividing the homogenate into quarters. Each chemical parameter was measured with five replications. Obtained average samples were immediately extracted (see the chapter 2.2 Sample preparation). Brief characteristics of the cultivars are as follows: ´Giant´ - large, golden-orange fruit, approximately one inch in diameter with a delicious flavor.

´Golden berry´ - yellow fruits with the average of one inch in diameter, with a flavorful and sweet pulp.

´Inka´ - round yellow fruits, one inch in diameter, with a slightly sour and sweet taste and pleasantly aromatic [4].

2.2 Sample preparation

The extraction was performed according to the modified method [12,13], using the following procedure: 10 g of a fresh sample was homogenized for 10 seconds in 100 mL of methanol in a laboratory grinder (SJ500, MEZOS, Hradec Kralove, Czech Republic). The resulting paste was placed into Erlenmeyer flasks (120 mL) and left to stand in a water bath at 25°C for a period of 24 hours. After the extraction the content of the flask was filtrated through paper Filtrapak No. 390 (Petr Lukes, Uhersky Brod, Czech Republic) and stored at 4ºC until further use.

2.3 Total phenolic content assay

To measure the total content of phenolic substances, 0.5 mL of the sample was taken and diluted with water in a 50 mL volumetric flask. Thereafter, 2.5 mL of Folin-Ciocalteau reagent and 7.5 mL of a 20% solution of sodium carbonate were added. The resulting absorbance was measured in a spectrophotometer (LIBRA S6, Biochrom Ltd., Cambridge, U.K.) at a 765 nm wavelength against a blind sample, which was used as reference. The results were expressed as grams of gallic acid (GAE) per kg^{-1} of fresh mass (FM) [13].

2.4 Antioxidant capacity by the DPPH and ABTS test assay

The DPPH (2,2-Diphenyl-1-picrylhydrazyl) test was conducted according to the modified method [14,15]. The stock solution was prepared by dissolving 24 mg of DPPH with 100 mL of methanol and then stored at -20°C until needed. The working solution was obtained

by mixing 10 mL of the stock solution with 45 mL of methanol to obtain the absorbance of 1.1±0.02 units at 515 nm using a spectrophotometer (LIBRA S6, Biochrom Ltd., Cambridge, UK). Fruit extracts (150 µL) were allowed to react with 2,850 µL of the DPPH solution for one hour in the dark. Then the post-reaction absorbance was measured (also at 515 nm).

Antioxidant capacity was measured using the ABTS (2,2´-azinobis-3-ethylbenzthiazino-6-sulphonic acid) method [16]. ABTS (54.9 mg) was dissolved in 20 mL of phosphate buffer (pH 7.0; c=5 mmol L^{-1}) and activated on a cation radical of $ABTS^{+}$ by means of addition of 1 g of MnO_2^{+}. Then, the resulting solution was intermittently stirred for an activation period of 30 min. Thereafter, the solution was centrifuged for 5 min at 9,275x*g* and filtered through a syringe filter (0.25 µm, Petr Lukes, Uhersky Brod, Czech Republic). An aliquot (2 mL) of the filtrate was diluted with the phosphate buffer to an absorbance of 0.500±0.01, which was measured at a wavelength of 734 nm. After the absorbance was measured, 0.5 mL of the fruit extracts was added and the new absorbance value was determined after 20 min.

Antioxidant capacity was calculated as a decrease in the absorbance value using the formula:

Antioxidant capacity (%)=$(A_0–A_1/A_0)x100$,

where A_0 is the absorbance of the control (without the fruit extract) and A_1 is the absorbance of the mixture containing the extract.

The results of the absorbance were converted using a calibration curve of the standard and expressed in ascorbic acid equivalents (AAE) – g kg^{-1} FM [17].

2.5 Total flavonoid content assay

The total flavonoid content was determined following [18]. In a 10 mL Eppendorf tube, 0.3 mL of the fruit extract, 3.4 mL of 30% ethanol, 0.15 mL of $NaNO_2$ (0.5 mol L^{-1}) and 0.15 mL of $AlCl_3 \cdot 6H_2O$ (0.3 mol L^{-1}) were added and mixed. After 5 min, 1 mL of NaOH (1 mol L^{-1}) was added, and the mixture was measured at the wavelength of 506 nm. The total flavonoid concentration was calculated from a calibration curve using rutin as the standard. The results were expressed in g kg^{-1} FM.

2.6 Reactive oxygen species scavenging activity assay

For the measurement of reactive oxygen species activity a 25% fruit extract was prepared in a phosphate buffer (c=50 mmol L^{-1}, pH 7.0). The hydroxyl radical scavenging activity was assayed according to the following method [19], 1 mL of the extract was mixed with 0.8 mL of a reaction buffer (phosphate buffer, 20 mmol L^{-1}, pH 7.4; deoxyribose, 1.75 µmol L^{-1}; iron ammonium sulphate, 0.1 µmol L^{-1}; and EDTA (Ethylenediaminetetraacetic acid), 0.1 µmol L^{-1})). Hydrogen peroxide (0.1 mL, 0.01 mol L^{-1}) was then added to the reaction solution. The solution was incubated for 10 min at 37ºC prior to the addition of 0.5 mL of 1% thiobarbituric acid and 1 mL of 2.8% trichloracetic acid. The mixture was boiled for 10 min and then cooled rapidly. The absorbance of the mixture was measured at 532 nm with the spectrophotometer (LIBRA S6,Biochrom Ltd., Cambridge, UK).

The assay of nitric oxide scavenging activity was performed according to the method [20], 1 mL of the extract was mixed with 1 mL of the reaction solution containing sodium nitroprusside (10 mmol L^{-1}) in the phosphate buffer (20 mmol L^{-1}, pH 7.4). The solution was then incubated at 37ºC for one hour. An aliquot (0.5 mL) of the incubated solution was then mixed with 0.5 mL of Griess reagent. The absorbance was measured at 540 nm.

The superoxide anion scavenging activity was conducted according to the method based on the reduction of cytochrome *c* [21]. An aliquot of the extract (1 mL) was mixed with 1 mL of the solution containing xanthine oxidase (0.07 U mL^{-1}), xanthine (100 µmol L^{-1}) and cytochrome *c* (50 µmol L^{-1}). After incubation at 20ºC for 3 min, the absorbance at 550 nm was determined.

All tests were performed in triplicate. The scavenging activities of hydroxyl radical, nitric oxide and superoxide anion were calculated as follows:

Scavenging activity (%)=$(A_0–A_1/A_0)x100$,

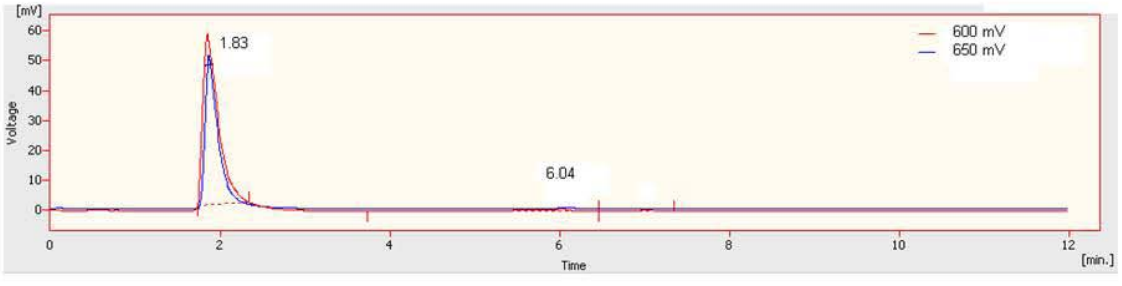

Figure 1. Chromatogram representing the peak of ascorbic acid of the ´Inka´ cultivar (the retention time 1.83 min, 600 mV).

where A_0 is the absorbance of the control (without the fruit extract) and A_1 is the absorbance of the mixture containing the extract.

2.7 Lipid peroxidation inhibition activity

The inhibition of lipid peroxidation was assayed by homogenizing 5 µg of rat liver in 20 mL of Tris-HCl buffer (50 mmol L^{-1}, pH 7.6). A sample of the liver homogenate (0.1 mL) was incubated with the fruit extract (0.2 mL of a 25% extract), 0.1 mL of KCl (30 mmol L^{-1}), 0.1 ml of $FeSO_4$ (0.16 mmol L^{-1}) and 0.1 mL of ascorbic acid (0.06 mmol L^{-1}) at 37ºC for 1 h. Thereafter, 1 mL of 1% thiobarbituric acid (TBA) and 1 mL of 15% trichloracetic acid were added. The final solution was heated at 100ºC in a boiling water bath for 15 min, cooled with ice for 10 min, and then centrifuged 4,724x*g* for 10 min (MPW-54,Unimed, Prague, Czech Republic). The absorbance of the supernatant was measured at 532 nm, using a spectrophotometer (LIBRA S6, Biochrom Ltd., Cambridge, UK). The control was performed by substituting Tris-HCl buffer (50 mmol L^{-1}, pH 7.6) for the fruit extract. The percentage of inhibition of the formation of TBA-reactive substances was calculated as:

Inhibition activity (%)=$(A_0–A_1/A_0)$x100,

where A_0 is the absorbance of the control (without the fruit extract) and A_1 is the absorbance of the mixture containing the extract [22].

2.8 Determination of ascorbic acid

The determination of ascorbic acid content was ascertained according to a modified method [23]. The homogenised fruit (5 g) were weighed in an Erlenmeyer flask and 25 mL of a solution containing extractant methanol:H_2O:H_3PO_4 in the ratio 99:0.5:0.5 was added. The flasks with the fruit extracts were placed into a water bath at 25°C, and the samples were extracted for 15 min. To protect the extracts from daylight, the flasks were covered with aluminium foil during the preparation. After the extraction the content of the individual flasks with different extracts were filtered (Filtrapak No. 390, Petr Lukes, Uhersky Brod, Czech Republic). Before injection, the filtrate prepared in this way was diluted in a ration of extractant methanol and filtered again through a membrane filter (Nylon 0.45 µm,Petr Lukes, Uhersky Brod, Czech Republic). The instrument used for ascorbic acid analysis consisted of a solvent delivery pump (Model 582, ESA Inc., Chelmsford, U.S.A.), a guard cell (Model 5010A, with a working electrode potential K1=600 mV, K2=650 mV, ESA Inc., Chelmsford, U.S.A.), a chromatographic column (Model Supelcosil LC8, 150.0x4.6 mm), 5 µm particle size and an electrochemical detector (Coulochem III, ESA Inc., Chelmsford, U.S.A.). The chromatographic conditions were constant: 30°C, a mobile phase comprising methanol:H_2O:H_3PO_4 in the proportion 99:0.5:0.5 was used (filtered through a Nylon filter, 0.2 µm), the type of elution was isocratic, the flow rate of the mobile phase was 1.1 mL min^{-1}. The content of ascorbic acid was calculated as g kg^{-1} FM.

2.9 Statistical analysis

The data obtained were analyzed statistically by the analysis of variance (ANOVA) and Tukey´s multiple range test for comparison of means [24]. Correlation functions were calculated using the statistical package Unistat, v. 5.1 and Office Excel® Microsoft, v. 2010.

3. Results and Discussion

The results of chemical analyses are provided in Tables 1 to 3. As can be seen, there were no statistically significant correlations between years (with the exception of the ´Giant´ cultivar and lipid peroxidation). However, significant differences were recorded in bioactive content and antioxidant activity between cultivars.

3.1 Total phenolic content, total flavonoid content and ascorbic acid content

The highest content of total phenolics was observed in the ´Inka´ cultivar. On average, this was 8.31 g of GAE per kg^{-1} FM in the year 2011 and 8.24 g of GAE per kg^{-1} FM for a three-year average. In addition, the contents of other chemical compounds (flavonoids and ascorbic acid) were the highest in this cultivar. The chromatogram representing the peak of ascorbic acid in the ´Inka´ cultivar is provided in Figure 1. Considerable variability in flavonoid and ascorbic acid content was recorded in particular cultivars, from 4.05 to 5.26 g kg^{-1} FM and 0.66 to 1.02 g kg^{-1} FM, respectively, which may be considered typical of edible berries [25]. The values are typical of most fruit species [26]. In general, with regard to one species variability may exist in the chemical composition [27,28], which was also confirmed in the research.

3.2 Antioxidant capacity and selected antioxidant properties

Antioxidant capacity was the highest in the ´Inka´ cultivar (ABTS test: 9.24 g of AAE kg^{-1} FM and DPPH test: 8.94 g of AAE kg^{-1} FM). Furthermore, the scavenging effects on NO, O, and OH in the ´Inka´ cultivar were 35.02%, 38.04% and 30.06%, respectively (three-year averages). The inhibition of lipid peroxidation in the ´Inka´ cultivar was 24.83% (three-year average). In the present paper, the Cape gooseberry fruit extract

Cultivar	Year	TPC	TAC (DPPH test)	TAC (ABTS test)
Giant	2009	6.32 ± 0.27[a]	7.11 ± 0.23[a]	7.26 ± 0.20[a]
	2010	6.14 ± 0.29[a]	7.05 ± 0.20[a]	7.20 ± 0.19[a]
	2011	6.51 ± 0.25[a]	7.25 ± 0.21[a]	7.33 ± 0.26[a]
Golden berry	2009	7.53 ± 0.21[b]	8.15 ± 0.25[b]	8.40 ± 0.31[b]
	2010	7.44 ± 0.24[b]	8.26 ± 0.28[b]	8.33 ± 0.26[b]
	2011	7.62 ± 0.19[b]	8.20 ± 0.24[b]	8.49 ± 0.27[b]
Inka	2009	8.17 ± 0.15[c]	8.93 ± 0.29[c]	9.17 ± 0.27[c]
	2010	8.25 ± 0.20[c]	8.98 ± 0.28[c]	9.25 ± 0.32[c]
	2011	8.31 ± 0.27[c]	8.90 ± 0.33[c]	9.31 ± 0.31[c]

Table 1. Total phenolic content (grams of gallic acid per kg^{-1} FM) and antioxidant activity (grams of AAE kg^{-1} FM) of fruits of three cultivars of Cape gooseberry (*Physalis peruviana L.*), n=15. Different superscripts in each column indicate the significant differences in the mean at $P<0.05$.

Cultivar	Year	TFC	AAC
Giant	2009	4.05 ± 0.20[a]	0.66 ± 0.10[a]
	2010	4.17 ± 0.15[a]	0.70 ± 0.12[a]
	2011	4.20 ± 0.14[a]	0.73 ± 0.10[a]
Golden berry	2009	4.75 ± 0.19[b]	0.99 ± 0.12[b]
	2010	4.70 ± 0.20[b]	0.95 ± 0.11[b]
	2011	4.76 ± 0.18[b]	0.97 ± 0.14[b]
Inka	2009	5.12 ± 0.11[c]	0.95 ± 0.09[b]
	2010	5.19 ± 0.16[c]	1.02 ± 0.14[b]
	2011	5.26 ± 0.18[c]	0.94 ± 0.10[b]

Table 2. Total flavonoid content and ascorbic acid contents (g kg^{-1} FM) of three cultivars of Cape gooseberry (*Physalis peruviana* L.), n=15. Different superscripts in each column indicate the significant differences in the mean at $P<0.05$.

Cultivar	Year	Nitric oxide (%)	Superoxide anion (%)	Hydroxyl radical (%)	Lipid peroxidation (%)
Giant	2009	28.22 ± 0.32[a]	31.64 ± 0.34[a]	24.11 ± 0.27[a]	19.72 ± 0.45[a]
	2010	28.12 ± 0.36[a]	30.90 ± 0.49[a]	23.68 ± 0.35[a]	18.44 ± 0.30[b]
	2011	28.51 ± 0.29[a]	31.51 ± 0.47[a]	24.10 ± 0.40[a]	19.79 ± 0.27[a]
Golden berry	2009	30.95 ± 0.20[b]	34.27 ± 0.37[b]	26.95 ± 0.33[b]	21.25 ± 0.31[c]
	2010	30.90 ± 0.29[b]	34.26 ± 0.41[b]	27.13 ± 0.38[b]	21.17 ± 0.28[c]
	2011	31.09 ± 0.33[b]	33.80 ± 0.47[b]	27.19 ± 0.30[b]	21.15 ± 0.27[c]
Inka	2009	35.12 ± 0.35[c]	38.04 ± 0.36[c]	29.89 ± 0.25[c]	24.55 ± 0.47[d]
	2010	34.69 ± 0.36[c]	37.86 ± 0.44[ac]	30.11 ± 0.31[c]	25.04 ± 0.51[d]
	2011	35.25 ± 0.31[c]	38.21 ± 0.40[c]	30.19 ± 0.28[c]	24.90 ± 0.45[d]

Table 3. Scavenging effect of three cultivars of Cape gooseberry (*Physalis peruviana* L.) extract (25%) on the percentage inhibition of nitric oxide, superoxide anion, hydroxyl radical and lipid peroxidation, n=15. Different superscripts in each column indicate the significant differences in the mean at $P<0.05$.

was evaluated for the ability to scavenge hydroxyl radical using the deoxyribose degradation assay. The scavenging activity of superoxide anion in the extracts of particular cultivars was also demonstrated in the xanthine/xanthine oxidase system. The coefficients of correlations existing between total contents of phenolics,

ascorbic acid, flavonoids and antioxidant capacity and scavenging effect on ROS and lipid peroxidation are given in in Tables 4 and 5.

Table 4 shows that the correlation coefficients between the measured chemical parameters expressing antioxidant properties of Cape gooseberry are high. As mentioned by many authors [17,29,30] this is a typical trait of the majority of fruit species not only in case of antioxidant capacity of phenolics but also flavonoids. Moreover, it is reported that the correlation between antioxidant capacity and the content of ascorbic acid is high in fruit [31].

Fruits of Cape gooseberry show relatively high values of antioxidant capacity. These values are much higher than those commonly referred to for the members of the genus *Prunus* [32]. For example, in cherries this value is on average 0.9 g of AAE per kg $^{-1}$ FM [33]. However, similarly high values, as those found in fruits of Cape gooseberry in the current study, are common in plums [17]. In apples, which are a typical representative of pomaceous fruit, the measured average values of antioxidant capacity are approximately 2.50 g of AAE per kg^{-1} FM [8]. Antioxidant capacities that are even higher than those recorded in plums or Cape gooseberries can be found, for example, in Chokeberries (*Aronia melanocarpa*) [34]. Other berry species with high anthocyan content, e.g. Blueberries (*Vaccinium corymbosum*) or Honeysuckles (*Lonicera caerulea*) show approximately a 50% higher antioxidant efficiency than Cape gooseberries. Similarly, reactive oxygen species scavenging activity also follows the same trend [35]. However, in spite of this, the fruit of the Cape gooseberry may be a suitable source of antioxidants in the domain of human nutrition. Other positive features of this plant species are a low demand in relation to soil and climatic conditions and a stable fruit-bearing capacity. The aim of the study was not to focus on the impact of climatic conditions on fruit. In regard to Cape gooseberry berries, previous studies have demonstrated the importance of climatic conditions on fruit nutritional content [36]. In that studyclimatic conditions were given considerable significance in relation to their effect on the chemical composition of berries. Definitely, there exists a need for further research in the field of environmental influences on the chemical composition of Cape gooseberries.

For the time being, looking for new food resources with antioxidant properties is one of the priorities in the food industry [37]. A great advantage of Cape gooseberry is that the fruits can be consumed fresh so that it is not necessary to cook or otherwise treat them. The quality of Cape gooseberry fruit is considerably influenced by preservation and other kinds of technological treatment and its antioxidant efficiency can therefore be reduced [38]. Besides the benefits of antioxidant properties for the human body it is also necessary to consider the impact of antioxidants on the shelf life, storability and resistance of fruit to various plant diseases and pests. From this point of view, Cape gooseberry seems to be a promising fruit species.

Correlation between	r^2	equation
TPC and TAC (DPPH test)	0.9871	y = 0.9218x + 1.3029
TFC and TAC (DPPH test)	0.9798	y = 1.6941x + 0.1486
AAC and TAC (DPPH test)	0.8048	y = 5.0433x + 3.6597
TPC and TAC (ABTS test)	0.9915	y = 1.0140x + 0.8356
TFC and TAC (ABTS test)	0.9908	y = 1.8699x – 0.4634
AAC and TAC (ABTS test)	0.7877	y = 5.4767x + 3.4910
TPC and hydroxyl radical	0.9743	y = 3.0822x + 4.3369
TFC and hydroxyl radical	0.9793	y = 5.7004 + 0.3105
AAC and hydroxyl radical	0.7235	y = 16.0940x + 12.8940
TPC and nitric oxide	0.9232	y = 3.3356x + 6.8594
TFC and nitric oxide	0.9506	y = 6.2438x + 2.1513
AAC and nitric oxide	0.9011	y = 1.0198x + 26.3290
TPC and superoxide anion	0.9252	y = 3.3154x + 10.0790
TFC and superoxide anion	0.9418	y = 6.1707 + 5.5651
AAC and superoxide anion	0.6141	y = 16.3680x + 20.1130
TPC and lipid peroxidation	0.8872	y = 2.7351x + 1.6337
TFC and lipid peroxidation	0.8932	y = 5.0624x – 1.9581
AAC and lipid peroxidation	0.5450	y = 12.9890x + 10.3630

Table 4. Correlation relationships between the total phenolic content, total flavonoid content, total antioxidant capacity, the ascorbic acid content, and the scavenging effect of Cape gooseberry extracts on hydroxyl radical, nitric oxide, superoxide anion and lipid peroxidation.

Chemical parameter	TAC (the DPPH test)	TAC (the ABTS test)	Hydroxyl radical	Nitric oxide	Superoxide anion	Lipid peroxidation
TPC	0.9871***	0.9915***	0.9743***	0.9232***	0.9252***	0.8872***
TFC	0.9798***	0.9908***	0.9793***	0.9506***	0.9418***	0.8932***
AAC	0.8048***	0.7877***	0.7235**	0.9011***	0.6141*	0.5450*

Table 5. Pearson correlation coefficients between investigated chemical parameters. The mean values were used in the analyses of chemical parameters at levels. *P<0.05; **P<0.01; ***P<0.001.

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